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Title:

Emulsified gelant

The present invention comprises a composition and a process that reduces the water permeability in a subterranean reservoir more than the oil permeability using an emulsified gelant. Further, the present application comprises the use of a composition comprising an aqueous gelant emulsified in oil .

5

Gels are used in reservoirs to reduce the water cut while maintaining, or even increasing, the oil production from a well.

To obtain a simple and cost effective treatment the gelant should be placed by
10   bullhead injection. In order not to impair the oil production, the gel must have some form of self-selectivity. One method is to use gels that reduces the permeability of water more than that of oil, so called disproportionate permeability reduction (DPR). The use of DPR-gels is limited to shut-off isolated water producing layers or to coning situations. (SPE 50983, Disproportionate
15   Permeability reduction is Not a Panacea, Stavland et al. 1998.)

It was demonstrated in "Mechanistic Study of Disproportionate Permeability Reduction", SPE/DOE 39635 (Nilsson, S., Stavland, A. and Jonsbråten, H.C.) that the DPR effects is controlled by the core wettability and the gelant saturation in
20   the core. The best DPR- effects have been found to occur in fractional wet media. To obtain a good DPR-effect, i.e. preserving the oil permeability and reduce the water permeability, it is important to preserve oil continuos channels. In homogeneous wetting media, oil continuos channels are easier to obtain in a oil wet media than in a water wet. In a water wet media aqueous gelants tend to
25   block narrow passages and especially pore throats with the result that also small amounts of gel gives rise to strong permeability reductions for both phases.

Apart from the wettability of the core material, which is determined by the reservoir and cannot be changed much, another important parameter is the gelant volume
30   fraction, which is comprised, in the present invention. Little can be done in practice with the wettability leaving the gelant saturation during placement as the operational variable. The volume fraction of the gel can be varied in two different

methods. One method is direct injection of the gelant at residual oil saturation, S_{or}, so that the gelant occupies the entire aqueous volume and that the gel then shrinks by synerising water. Another possible method is to inject gelant together with oil. Coinjection of gelant and oil is found to be successful. The important

5   parameter is the oil saturation in the core during placement. It is important to realise that the saturation in the core is a function of both the relative permeability curves and the oil/gelant ratio during placement. The saturation in the core is not the same as the saturation in the injected stream, which is a disadvantage for practical applications since reliable relative permeability curves are not always

10   available. The disadvantage with coinjection is that it is easy to carry out in the laboratory, but very difficult to do in the field.

The present invention describes the mechanisms of DPR-gels and how DPR-gels can be optimised. Further on the present invention comprise DPR gels which

15   reduce the permeability of water with little or no impact on the oil permeability. One important motivation for developing DPR gels is more simple and cost effective implementation, i.e., by bullhead injection, but it is important to optimise the use of DPR gel systems.

20   To optimise the DPR effect it is important to place the gel at oil saturation higher than the residual. The present invention comprises injection of a gelant as an emulsion dispersed in oil. When gelant is emulsified in oil, it can be treated and pumped as a pseudo one-component system. The emulsion should not be too stable and preferably break spontaneously within a couple of hours.

25

The present application comprises a composition and a process for reducing the water permeability more than the oil permeability in a subterranean reservoir, which composition comprises an aqueous gelant emulsified in oil. The gelant in the present invention comprises water soluble polymers, preferably

30   polyacrylamides, polyacrylate copolymers or biopolymers which is present in a concentration sufficient to give a stable gel after crosslinking, usually in the concentration range of form 1000 to 50000 ppm, more preferably in the

concentration range of from 2000 to 10000 ppm. The composition and process according to the invention also include one or several crosslinking agents which is hexamethylenetetramine and/or salicyl alcohol and/or trivalent metal ions preferably chromium or aluminium. The crosslinking agents is present in a

5 concentration range of from 50-5000ppm, preferably in a concentration range of from 100-1000ppm. The emulsion of the present invention is stabilised by a surfactant, preferably an oil soluble surfactant, which is present in a concentration range of from 0.05 to 10%, preferably in the range of from 0.1 to2%. The emulsion of the invention is not too stable and breaks in 1-15 hours at a

10 temperature of from 50-130°C. The emulsion can be considered as a pseudo one-component system. Another important feature of the emulsion is that it breaks spontaneously before a gel is formed. The use of a composition comprising an aqueous gelant emulsified in oil for reducing the water permeability more than the oil permeability in a subterranean reservoir is also described in the present

15 invention. The gelant concentration in the emulsion is in the range up to 50 volume%, preferably in the range of 5-50%, and the gelant emulsified in oil comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers.

20 An emulsified gelant is prepared by taking a water based polymer and cross linker dissolved in brine. The gelant is then emulsified in oil with an added surfactant as emulsion stabiliser. An example of an emulsified gelant is as follows. The gelant used here was HE 300 /HMTA/salicylalcohol in Isopar oil added an oil soluble surfactant as emulsion stabiliser but any aqueous gelant could have been used.

25 The emulsion breaks in a couple of hours at 90°C, and before gel is formed. The gel formed does not synerese. We are now able to tailoring the selectivity only by the gelant concentration in the oil.

Emulsified gelants has been found to be useful as DPR systems. The permeability

30 reduction for both oil and water follows a simple, in fact almost linear, relation as a function of saturation in the core after placement. Emulsified systems are easier to handle and predict than the previously evaluated coinjection of oil and gelant.

(Nilsson, S., Stavland, A. and Jonsbråten, H.C.: "Mechanistic Study of disproportionate Permeability Reduction", SPE/DOE 39635.

From the experimental result concerning the emulsified gelant systems, the
emulsified gelants behave effectively as a pseudo-one-component system. The
saturation in the core becomes approximately the same as the gelant content in
the emulsion (figure 1). The efficiency of the emulsion in terms of selectivity is
quite similar to the previously investigated coinjection of gelant and emulsion if the
comparison is made in terms of residual resistance factors (figure 10).

The gelant saturation in the core and the gelant saturation in the emulsion are not
exactly the same and the deviation has been in the range 1 – 12% units for the
fractional wet cores. If emulsions could be considered as perfect pseudo one-
component systems there should have been no deviations at all.

In water wet media the permeability reduction was much stronger, when using a
gelant with the saturation of gelant in the oil (25%) since an aqueous gelant in a
water wet media blocks narrow passages like pore throats. With the present
invention it is important to notice that it is possible to obtain a measurable
permeability reduction instead of a complete blocking. The reason is that the oil
(in the emulsion) helps to keep some channels open so that it is possible for oil to
flow through the core without first having to break the gel mechanically.

An important difference between water wet and fractional wet media in the present
application is that the saturation in the core after placement differed significantly
from the saturation in the emulsion. The saturation in the water wet core after
placement was 58% as compared to 25% in the emulsion. In fractional wet cores
the difference is much less and about 1 – 12 %. This shows that the core material
"traps" the wetting fluid.

Figure 1 shows saturation after placement in a fractional wet core as a function of
% gelant in the injected emulsion.

Figures 2-9 shows relative permeability curves before and after gel treatment for oil and water.

5   Figures 10-12 shows residual resistance factor for oil as a function of residual resistance factor of water after gel treatment of fractional wet cores.

Examples

10   <u>Experimental arrangement</u>

The chemicals that have been used are:

Synthetic seawater: the composition is as indicated in the table below

15   Table 1. Composition of synthetic sea water.

Salt	Conc. (g/litre)
NaCl	24.79
$MgCl_2 \cdot 6H_2O$	11.79
$CaCl_2 \cdot 2H_2O$	1.60
KCl	0.80
$SrCl_2 \cdot 6H_2O$	0.02
Na_2SO_4	4.14
$NaHCO_3$	0.21

Oil: Isopar H, a high boiling alkane fraction produced by Exxon.

20   *Gelants:* Waterbased polymer with a corresponding crosslinker giving a suitable gelation time.

Surfactant: A surfactant has been used to stabilise the emulsified gelants in oil.

25   Flooding experiments in sand-packs were carried out in 2 cm diameter columns with a length of ca 30 cm. Coarse glass filters (por 1) were mounted at the inlet and outlet. The pressure ports on the columns were 25 cm apart and about 2.5 cm

from the ends. Two different types of sand have been used. Acid cleaned quartz sand, 50-75 µm particle size, which is water wetting, and Teflon powder which is oil wetting. The Teflon powder was delivered by Avocado Research Chemicals and was in the form of small granules with internal pores.

5

Two different system were used to pack the columns:

1. Mixture of quartz sand and Teflon powder, 50/50 by volume, referred to as
10 fractional wet

2. Quartz sand only, referred to as water-wet

The cores thus obtained have well defined wettability properties, fractional wet
15 and water-wet. The permeabilities was about 2000 mD before gel treatment and porosities about 45-55%. The permeabilities to brine (synthetic sea water) and oil before and after gel injection were measured at room temperature by the following procedure:

20 1. The column was first saturated by oil.

2. Water was injected at low flow rate, 0.5 ml/min, until no more oil was produced and the water saturation (S_w) and permeability of water (k_w) were measured.

25
3. The injection rate of water was increased step wise and S_w and k_w were measured at each step at steady state.

4. Oil was injected. S_w and the oil permeability (k_o) were measured in the same
30 way as above.

5. Gelant were injected until steady state was reached.

6. The cores were shut in for 3 days at 90°C.

35

7.   The cores were taken out to room temperature and water was injected at low rate, 0.1 ml/min, S_w and water permeability after gel treatment ($k_{w,gel}$) were measured, the injection rate of water was increased step wise and S_w and $k_{w,gel}$ were measured at each step at steady state.

5

8.   Oil was injected. S_w and oil permeability after gel treatment ($k_{o,gel}$) were measured in the same way as above.

9.   Occasionally water was injected again and S_w and $k_{w,gel}$ were measured as
10 above to check for gel stability.

The residual resistance factors (RRF) and tables that are quoted in the present application are the ratios between the endpoint permeabilities taken before and after gel treatment.

15

The tables 4-10 demonstrate data which is common to all core floods at the following conditions:

Length between pressure ports 25.1 cm, dead volume 1.74 ml. Area 3.14 cm^2,
20 total length ca 30 cm, viscosity of water 1 cP and oil 1.15cP.

Units used in the table are psi for the pressure (DP), ml/min for the flow rate, produced volumes of oil and water in cumulative ml.

25 · **Example 1 - Emulsified gelant**

In the work from 1997 of Nilsson, S., Stavland, A. and Jonsbråten, H.C.: "Mechanistic Study of Disproportionate Permeability Reduction", SPE/DOE 39635 it was found that useful DPR effects, i.e. preserving the oil permeability as much
30 as possible and at the same time reduce the water permeability, could be obtained by coinjecting oil and gelant. The important parameter is the oil saturation in the core during placement. The purpose of this activity is to evaluate weather or not these problems can be circumvented by injecting the gelant as an emulsion. When gelant is emulsified in oil it can be treated and pumped as a pseudo one-
35 component system.

A non-emulsified gelant, 100% gelant and no oil, is included as a comparison below.

Recipe and properties of emulsified gelant.

5

The gelant used in all the emulsion experiments was HE300 with HMTA and salicylalcohol. The concentration was 5000 ppm HE 300 with 1000 ppm HMTA and 2000 ppm salicylalcohol added as crosslinker. The polymer solution was sheared in a Silverson mixer at 3/4 of maximum speed for 15 minutes.

10

The gelant (non-emulsified) was found to gel over night at 90 °C. There was no gelation at room temperature within one month.
The emulsion was prepared by dispersing the gelant in Isopar and mixing with the Silverson mixer at 3/4 of maximum speed for 5 minutes.

15

An oil soluble surfactant, was used as an emulsion stabiliser and was found to be adequate, the surfactant concentration was 0.5% in the oil phase. An oil soluble surfactant was selected since these tend to favour oil continuos emulsions. Emulsion viscosity is about 10-20 cp depending on shear and gelant/oil ratio. The

20 viscosity of the polymer solution alone was 10 cp.

The emulsion breaks in a couple of hours at 90 °C. At room temperature the emulsion breaks partly and gentle stirring is needed to maintain the system as an emulsion. In bulk samples at 90 °C the emulsion breaks before the gel has formed.

25

Core flood:

A series of core floods has been carried out using different gelant/oil ratios. The core material has been fractional wetting, quartz/Teflon in most of the core floods. In one of the core floods the packing material was water wet quartz. The results are summarised in tables 2 and figures 1-5. More detailed data on the core floods are given in experimental arrangement.

The emulsions could be injected in the cores without problem and behaved like a one-phase fluid with a viscosity of about 10 cP. The fluid was also produced as an emulsion at the outlet (after breakthrough). It was found that the saturation in the

5 core became somewhat higher but still about the same as the saturation of the injected emulsion (figure 1). The emulsion system is thus a simple way to control the saturation during placement as compared to co-injection of oil and gelant where the relative permeability curves need to be considered. Since the effluent was an emulsion the saturation after placement could not be obtained in the usual

10 way from produced volumes of oil and water. Instead a chloride titration was carried out at the very end of the core floods and the saturation was then obtained by calculating backwards from the produced volumes.

With 15% gelant in the emulsion the result was a rather weak permeability

15 reduction with an insignificant selectivity (figure 2). The water flooding after gelation was also stopped at an early stage since it looked as if small gel aggregates were produced from the core. The end point saturation for water may therefore be unrealistically low compared to the other floods. No such indications were observed in the floods with higher gelant contents in the emulsions.

20

If the gelant concentration in the emulsion is increased the result is a clear disproportionate permeability reduction where the selectivity increases as the overall permeability reduction increases. The highest gelant concentration used was 50%, which resulted in a permeability reduction for water of 350 and a factor

25 of 9.0 for oil. Intermediate gelant concentrations naturally produced intermediate permeability reductions, for instance 20% gelant gave $RRF_w = 2.9$ and $RRF_o = 1.6$, in a repeat core flood with 20% gelant the result was $RRF_w = 23$ and $RRF_o = 3.5$. The difference between the two experiments can be traced to the fact that the gelant saturation in the core was higher in the repeat experiment, see table 2 and

30 figure 1.

As can be seen in table 2 the use of emulsified gelant gives a considerable

protection of the oil permeability as compared to the use non-emulsified gelant (100%).

The relative permeability curves are given in figures 1-9.

5

Table 2. Summary on experimental result using emulsified gelant and fractional wet cores.

Gelant content in the emulsions and saturation after plament (S_w (gel))	Residual resistance factors	Selecti-vity RR_w/ RRF_o	Endpoint permeability for oil/endpoint saturation before and after gel treatment	Endpoint permeability for brine/endpoint saturation before and after gel treatment
15% gelant in emulsion, S_w (gel) = 0.16	RRF_w = 1.4 RRF_o = 1.3	1.08	k_o = 1745 (S_w = 0.09) $k_{o,g}$ = 1324 (S_w = 0.17)	k_w = 2120 (S_w = 0.51) $k_{w,g}$ = 1521 (S_w = 0.46)
20% gelant in emulsion (1), S_w (gel) = 0.23	RRF_w = 2.89 RRF_o = 1.61	1.80	k_o 2182 (S_w = 0.06) $k_{o,g}$ = 1351 (S_w = 0.13)	k_w = 2858 (S_w = 0.50) $k_{w,g}$ = 988 (S_w = 0.54)
20% gelant in emulsion (2), S_w (gel) = 0.32	RRF_w = 23 RRF_o = 3.5	6.6	k_o 1331 (S_w = 0.06) $k_{o,g}$ = 382 (S_w = 0.23)	k_w = 1725 (S_w = 0.50) $k_{w,g}$ = 75 (S_w = 0.60)
25% gelant in emulsion, S_w (gel) = 0.36	RRF_w = 2.64 RRF_o = 1.80	1.5	k_o = 1512 (S_w = 0.10) $k_{o,g}$ = 842 (S_w = 0.18)	k_w = 1776 (S_w = 0.49) $k_{w,g}$ = 673 (S_w = 0.56)
30% gelant in emulsion, S_w (gel) = 0.41	RRF_w = 43 RRF_o = 5.6	7.68	k_o = 1801 (S_w = 0.05) $k_{o,g}$ = 319 (S_w = 0.25)	k_w = 2199 (S_w = 0.46) $k_{w,g}$ = 51 (S_w = 0.52)
50% gelant in emulsion, S_w (gel) = 0.57	RRF_w = 350 RRF_o = 9.0	39	k_o = 1894 (S_w = 0.09) $k_{o,g}$ = 209 (S_w = 0.34)	k_w = 2317 (S_w = 0.50) $k_{w,g}$ = 6.6 (S_w = 0.65)
100% gelant (no emulsion), S_w (gel) = 1	RRF_w = 1000 RRF_o = 16	62	k_o = 2136 (S_w = 0.21) $k_{o,g}$ = 132 (S_w = 0.43)	k_w = 2618 (S_w = 0.60) $k_{w,g}$ = 2.7 (S_w = 0.63)

With the water-wet core the permeability reduction was much stronger (figures 8-9 and table 3). A emulsion with 25% gelant gave RRFW = 214 which is almost 100 times more than a 25% emulsion in fractional wet cores. The emulsion system does however give a pronounced DPR effect also in water wet media.

Table 3. Summary on experimental result using emulsified gelant and a water-wet core.

Gelant content in the emulsions and saturation after plament (S_w (gel))	Residual resistance factors	Selecti-vity RR_w/RRF_o	Endpoint permeability for oil/endpoint saturation before and after gel treatment	Endpoint permeability for brine/endpoint saturation before and after gel treatment
25% emulsion, S_w (gel) = 0.58	RRF_w =214 RRF_o = 18	12	k_o = 2548 (S_w = 0.21) $k_{o,g}$ = 142 (S_w = 0.34)	k_w = 1539 (S_w = 0.77) $k_{w,g}$ = 7.2 (S_w = 0.77)
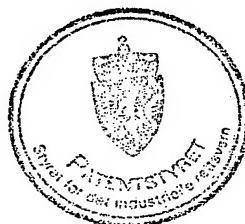
Table 4
Exp. 1: Pore volume = 42.79 ml, fractional wet

inj sw	oil prod	saturation	DP	perm	rate
	21.9	0.47	0.8	1223	0.5
	23.4	0.51	1.28	1529	1
	24.5	0.53	2.1	1864	2
	24.6	0.53	4.1	1910	4
	24.9	0.54	6.2	1894	6

inj oil	sw prod	saturation	DP	perm	rate
	16	0.21	0.93	1210	0.5
	18.1	0.16	1.52	1481	1
	20	0.11	2.92	1542	2
	20.5	0.10	5.49	1640	4
	20.8	0.10	8.12	1663	6

inj sw	oil prod	saturation	DP	perm	rate
	19.8	0.52	1.25	1566	1
	20.9	0.54	2.1	1864	2
	21.2	0.55	4.45	1760	4
	21.55	0.56	6.55	1793	6

	prod		DP		rate
gelant	0		2.06		0.23

inj sw	oil prod	saturation	DP	perm	rate
	1.7	0.62	35	0.06	0.001

inj olje	sw prod	saturation	DP	perm	rate
	3.5	0.49	6.27	0.72	0.002
	6.3	0.43	11.3	0.80	0.004
	8	0.39	13.4	1.68	0.01
	9	0.37	20	2.25	0.02
	10.4	0.33	20.5	4.39	0.04
	11.6	0.31	22.5	8.00	0.08
	12.1	0.29	22	10.23	0.1
	12.9	0.27	24.6	13.73	0.15
	13.5	0.26	24.5	18.38	0.2
	14.9	0.23	17.6	38.37	0.3

inj sw	oil prod	saturation	DP	perm	rate
	15.1	0.54	41	0.10	0.002

Table 5
Exp. 2: Pore volume = 44.56 ml, fractional wet

inj sw	oil prod	saturation	DP	perm	rate
	19.8	0.41	0.18	1088	0.1
	21.7	0.45	0.75	2610	1
	22.1	0.46	1.59	2462	2
	22.5	0.47	2.89	2709	4
	22.8	0.47	4.3	2731	6

inj oil	sw prod	saturation	DP	perm	
	18.3	0.20	0.59	1908	0.5
	19.4	0.18	1.12	2010	1
	20.1	0.16	2.19	2056	2
	20.9	0.14	4.19	2149	4
	21.5	0.13	6.13	2203	6

inj sw	oil prod	saturation	DP	perm	
	16.9	0.37	0.7	1398	0.5
	17.8	0.39	1.05	1864	1
	19.4	0.43	3.33	2351	4
	20.3	0.45	4.31	2725	6

			DP		
gelant			13.2		2.3

inj sw	oil prod	saturation	DP	perm	
	3.2	0.52	24.9	0.39	0.005

inj oil	sw prod	saturation	DP	perm	
	3.4	0.48	6.3	3.6	0.01
	4.5	0.46	9.67	7.0	0.03
	6.8	0.41	11.52	19.5	0.1
	8.7	0.36	10.98	41.0	0.2
	8.9	0.36	20.99	42.9	0.4
	10.7	0.32	15.96	112.8	0.8

Table 6

20% emulsion (2), fractional wet:

Pore volume = 40.0

inj sw	oil prod	saturation	DP	perm	rate
	19.6	0.446	0.19	1030	0.1
	21.2	0.486	0.63	1554	0.5
	21.75	0.500	1.13	1732	1
	21.75	0.500	2.31	1695	2
	21.8	0.501	4.56	1717	4
	21.9	0.504	6.81	1725	6
inj oil	sw prod	saturation	DP	perm	rate
	15.9	0.150	0.37	608	0.1
	18	0.097	1.04	1082	0.5
	18.5	0.085	1.88	1197	1
	18.8	0.077	3.63	1240	2
	19.3	0.065	6.87	1311	4
	19.4	0.062	10.15	1331	6
gelant			9.56		1.
inj sw	oil prod	saturation	DP	perm	rate
	9.9	0.570	7.81	1.3	0.00
	10.4	0.582	9.78	2.0	0.01
	10.6	0.587	12.94	7.6	0.05
	10.7	0.590	14.4	13.6	0.1
	11.3	0.605	19.2	51.0	0.5
	11.3	0.605	27.11	72.2	1
inj oil	sw prod	saturation	DP	perm	rate
	8.2	0.443	2.3	9.8	0.01
	8.6	0.433	3.21	14.0	0.02
	10.3	0.391	3.49	32.3	0.05
	11.65	0.357	4.3	52.4	0.1
	12.3	0.341	4.49	100.3	0.2
	14.3	0.291	7.19	156.5	0.5
	16	0.248	9.27	242.8	1
	16.9	0.226	13.2	341.1	2
	16.9	0.226	23.58	381.9	4

Table 7

25% emulsion, fractional wet:

Pore volume = 40.0

| inj sw	oil prod	saturation	DP	perm	rate
	21.2	0.460	0.58	1687.	0.5
	21.45	0.466	1.2	1631.	1
	21.6	0.470	2.39	1638.	2
	21.7	0.472	4.73	1655.	4
	22.3	0.487	6.61	1776.	6
inj oil	sw prod	saturation	DP	perm	rate
	12.6	0.271	0.36	625.3	0.1
	16.1	0.188	0.91	1236.	0.5
	17.3	0.159	1.72	1308.	1
	18	0.143	3.23	1393.	2
	19.5	0.107	6.05	1488.	4
	19.7	0.103	8.93	1512.	6
gelant			9.1		1
inj oil	sw prod	saturation	DP	perm	rate
	1.2	0.353	0.93	242.1	0.1
inj sw	oil prod	saturation	DP	perm	rate
	8.9	0.522	2.74	35.7	0.05
	9.6	0.539	3.16	61.9	0.1
	9.6	0.539	3.53	277.3	0.5
	10.2	0.553	5.15	380.1	1
	10.5	0.560	8.45	463.3	2
	10.6	0.562	13	602.3	4
	10.7	0.565	17.44	673.5	6
inj oil	sw prod	saturation	DP	perm	rate
	13.2	0.293	1.05	214.4	0.1
	16.4	0.218	2.55	441.4	0.5
	17.5	0.192	3.72	605.1	1
	18.1	0.177	6.24	721.5	2
	18.2	0.175	10.69	842.3	4

Table 8
30% emulsion, fractional wet

Pore volume = 44.4

inj sw	oil prod	saturation	DP	perm	rate
	20.7	0.427	0.55	1780	0.5
	20.75	0.428	1.1	1780	1
	21.8	0.452	1.99	1967	2
	22.2	0.461	3.67	2134	4
	22.4	0.465	5.34	2199	6
inj oil	sw prod	saturation	DP	perm	rate
	13.95	0.190	0.28	804	0.1
	16.95	0.123	0.82	1373	0.5
	16.95	0.123	1.62	1390	1
	19.5	0.065	2.76	1631	2
	20.2	0.050	5.1	1766	4
	20.2	0.050	7.5	1801	6
gelant			7.59		1.
inj oil	sw prod	saturation	DP	perm	rate
	0.4	0	1.93	117	0.1
inj sw	oil prod	saturation	DP	perm	rate
	4.9	0.406	8.28	0.5	0.00
	8.65	0.490	10	1.0	0.00
	9.3	0.505	11.03	1.8	0.01
	9.4	0.507	11.66	3.4	0.02
	9.5	0.509	13.43	7.3	0.05
	9.8	0.516	15.04	13.0	0.1
	10.2	0.525	19.11	51.2	0.5
inj oil	sw prod	saturation	DP	perm	rate
	7.2	0.402	1.97	11	0.01
	7.2	0.402	4.94	23	0.05
	7.4	0.398	5.22	43	0.1
	10.2	0.334	7.93	142	0.5
	12.3	0.287	12.92	174	1
	12.7	0.278	17.54	257	2
	13.8	0.253	28.23	319	4

Table 9
50% emulsion, fractional wet

Pore volume = 44.77

inj sw	oil prod	saturation	DP	perm	rate
	20.1	0.41	0.11	1780	0.1
	22.4	0.46	0.4	2447	0.5
	23.1	0.48	0.84	2330	1
	23.4	0.48	1.7	2303	2
	23.6	0.49	3.66	2139	4
	24.14	0.50	5.08	2312	6
inj oil	sw prod	saturation	DP	perm	
	15.2	0.200	0.27	834	0.1
	17.4	0.151	0.84	1340	0.5
	18.6	0.124	1.4	1608	1
	19.1	0.113	2.66	1693	2
	19.9	0.095	4.93	1826	4
	20.0	0.093	7.13	1894	6
inj sw	oil prod	saturation	DP	perm	
	14.3	0.413	0.71	1379	0.5
	15.2	0.433	1.25	1566	1
	16.7	0.466	1.96	1997	2
	16.9	0.471	3.89	2013	4
	17.1	0.475	5.65	2079	6
	17.8	0.491	5.07	2317	6
gelant			13.3		1
inj sw	oil prod	saturation	DP	perm	
	7.4	0.60	9.24	4.24	0.02
	9.4	0.65	11.8	6.64	0.04
inj oil	sw prod	saturation	DP	perm	
	10.6	0.451	2.13	106	0.1
	13.9	0.377	2.85	158	0.2
	15.6	0.339	4.51	200	0.4
	15.7	0.337	6.45	209	0.6
inj sw	oil prod	saturation	DP	perm	
	14.3	0.618	7.02	6.41	0.02

Table 10
25% emulsion, water wet. Pore volume = 37.39

inj sw	oil prod	saturation	DP	perm	rate
	29.8	0.750	0.75	1305.	0.5
	29.6	0.745	1.34	1460.	1
	29.8	0.750	2.65	1477.	2
	30	0.756	5.39	1452.	4
	30.4	0.767	7.63	1539.	6

inj oil	sw prod	saturation	DP	perm	rate
	13.1	0.464	0.36	625.3	0.1
	17.4	0.349	0.68	1655.	0.5
	17.8	0.338	1.28	1758.	1
	20.7	0.261	2.03	2217.	2
	22.1	0.223	3.68	2446.	4
	22.6	0.210	5.3	2548.	6

gelant		0.584	5.61		1

inj oil	sw prod	saturation	DP	perm	rate
	2.2	0.571	2.07	108.8	0.1

inj sw	oil prod	saturation	DP	perm	rate
	9.7	0.784	20.73	0.378	.004
	10.2	0.798	23.21	0.843	0.01

inj oil	sw prod	saturation	DP	perm	rate
	6.6	0.668	3.62	6.2	0.01
	8.5	0.617	3.54	12.7	0.02
	11	0.550	4.4	25.6	0.05
	14.2	0.464	4.12	54.6	0.1
	17.1	0.387	6.53	172.4	0.5
	18.9	0.339	15.83	142.2	1

inj sw	oil prod	saturation	DP	perm	rate
	17.9	0.771	27.2	7.20	0.1

Claims :

1. Composition for reducing water permeability more than oil permeability in a subterranean reservoir, which composition comprises an aqueous gelant emulsified in oil.

2. Composition according to claim 1, wherein the gelant concentration in the emulsion is in the range up to 50 volume%, preferably above 5 volume%.

3. Composition according to claim 1-2, wherein the gelant comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers.

4. Composition according to claim 1-3, wherein the polymer concentration in the gelant is present in a concentration sufficient to give a stable gel after crosslinking, usually in the concentration range of form 1000 to 50000 ppm, preferably in the concentration range of from 2000 to 10000 ppm.

5. Composition according to claim 1-4, wherein the gelant comprises one or several crosslinking agents, preferably hexamethylenetetramine and/or salicyl alcohol and/or trivalent metal ions preferably chromium or aluminium .

6. Composition according to claim 5, wherein one or several crosslinking agents is present in a concentration range of from 50-5000ppm, preferably in a concentration range of from 100-1000ppm.

7. Composition according to claim 1-6, wherein the emulsion is stabilised by a surfactant, preferably an oil soluble surfactant.

8. Composition according to claim 7, wherein the surfactant is present in a concentration range of from 0.05 to 10%, preferably in the range of from 0.1 to2%.

9. Composition according to claim 1-8, wherein the emulsion breaks in 1-15 hours at a temperature of from 50-130°C.

10. Composition according to claim 1-8, wherein a gel is formed after the emulsion breaks.

11. Process for reducing the water permeability more than the oil permeability in a subterranean reservoir, wherein an aqueous gelant emulsified in oil is injected into a reservoir.

12. Process according to claim11, wherein the gelant concentration in the emulsion is in the range up to 50 volume%, preferably above 5-volume%

13. Process according to claim 11-12, wherein the gelant emulsified in oil comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers.

14. Process according to claim 11-13, wherein the polymer concentration in the gelant emulsified in oil is present in the concentration sufficient to give a stable gel after crosslinking, usually in the concentration range of from 1000 to 50000 ppm, preferably in the concentration range of from 2000 to 10000 ppm.

15. Process according to claim 11-14, wherein the gelant comprises one or several crosslinking agents, preferably hexamethylenetetramine and/or salicyl alcohol, and/or trivalent metal ions preferably chromium or aluminium.

16. Process according to claim 11-15, wherein one or several crosslinking agents are present in the range of from 50 – 5000 ppm, preferably in the concentration range of from 100-1000ppm.

17. Process according to claim 11-16, wherein the emulsion is stabilised by a surfactant, preferably an oil soluble surfactant.

18. Process according to claim 17, wherein the surfactant is present in a concentration range of from 0.05 to 10%, preferably in the range of from 0.1 to 2%.

19. Process according to claim 11-18, wherein the emulsion breaks in 1-15 hours at a temperature of 50 - 130°C.

20. Process according to claim 11-19, wherein a gel is formed before the emulsion breaks.

21. Use of a composition comprising an aqueous gelant emulsified in oil for reducing the water permeability more than the oil permeability in subterranean reservoir.

22. Use according to claim 21, wherein the gelant concentration in the emulsion is in the range up to 50 volume%, preferably in the range of 5-50%.

23. Use according to claim 21-22, wherein the gelant emulsified in oil comprises water soluble polymers, preferably polyacrylamides, polyacrylate copolymers or biopolymers.

24. Use according to claim 21-23, wherein the polymer concentration in the gelant emulsified in oil is present in the concentration range of from 1000 to 50000 ppm, preferably in the concentration range of from 2000 to 10000 ppm.

25. Use according to claim 21-24, wherein the gelant comprises one or several crosslinking agents, preferably hexamethylenetetramine and/or salicyl alcohol, and/or trivalent metal ions preferably chromium or aluminium.

26. Use according to claim 21-25, wherein one or several crosslinking agents are present in the range of from 50 – 5000 ppm, preferably in the concentration range of from 100-1000 ppm.

5   27. Use according to claim 21-27, wherein the emulsion is stabilised by a surfactant, preferably an oil soluble surfactant.

28. Use according to claim 27, wherein the surfactant is present in a concentration range of from 0.05 to 10%, preferably in the range of from 0.1 to2%.

10

29. Use according to claim 21-28, wherein the emulsion breaks in 1-15 hours at a temperature of 50-130°C.

30. Use according to claim 21-29, wherein a gel is formed after the emulsion

15   breaks.
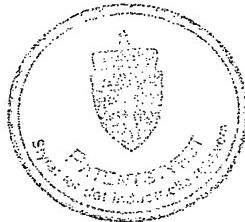
Abstract

Composition and a process for reducing the water permeability more than the oil permeability using an gelant emulsified in oil. The use of a composition comprising

5   an aqueous gelant emulsified in oil is also included in the present invention.
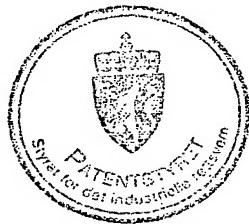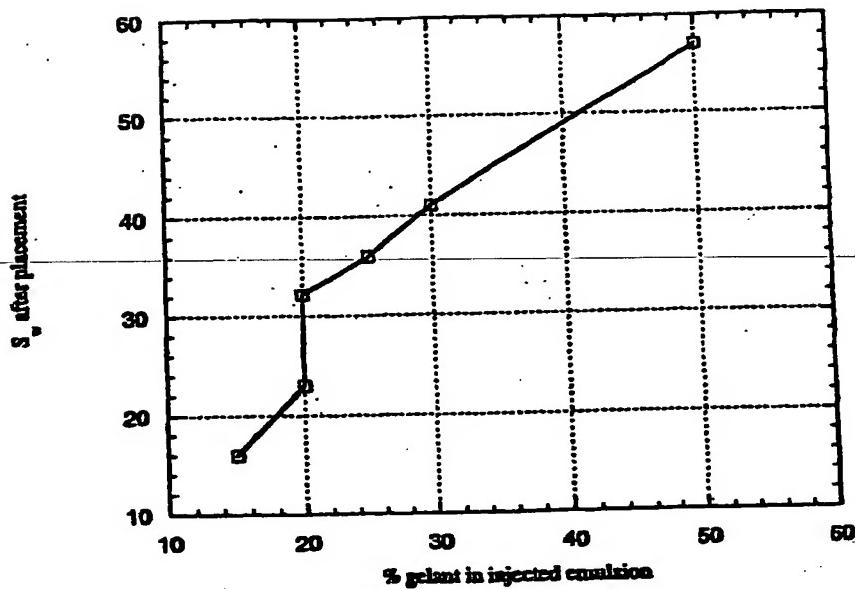
Figure 1. Saturation after placement in a fractional wet core as a function of % gelant in the injected emulsion.
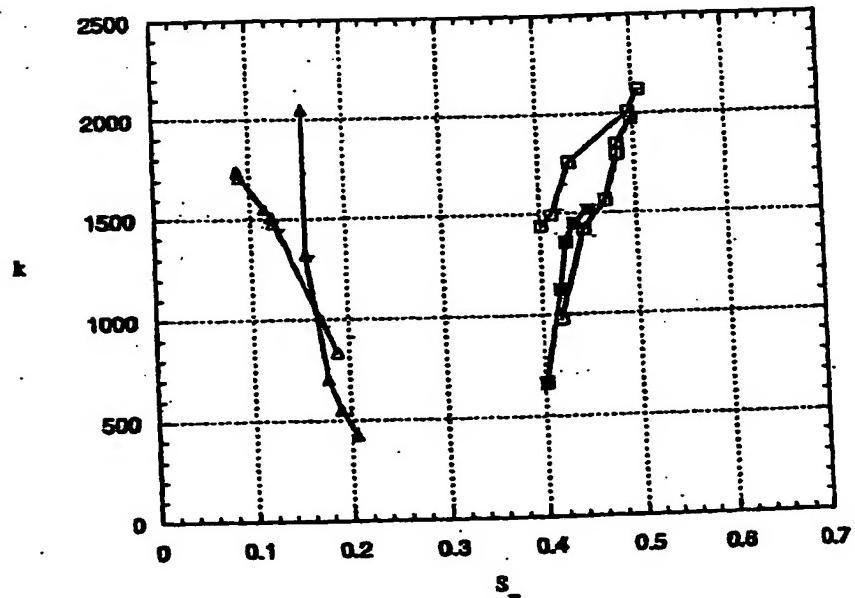
Figure 2. 15% gelant in the emulsion, fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).
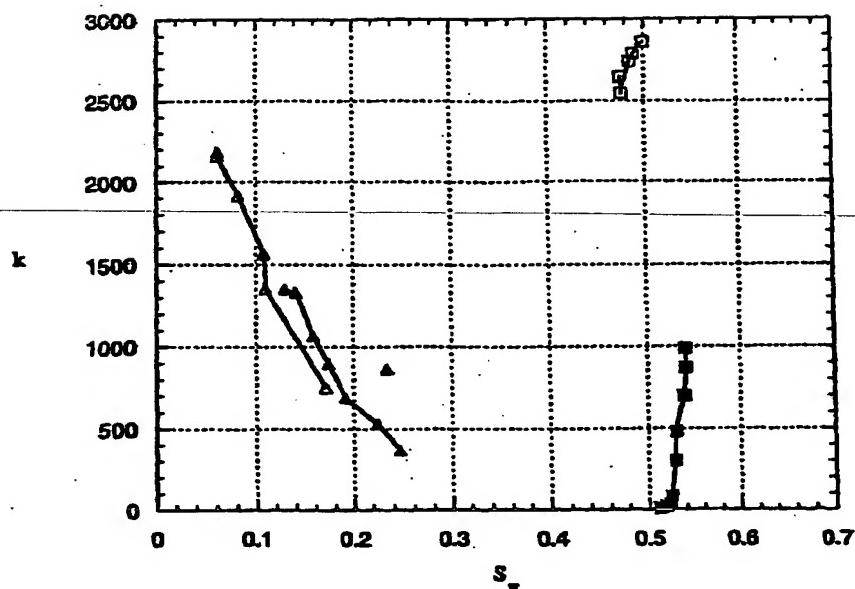
Figure 3. 20% gelant in the emulsion, fractional wet (run 1). Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).
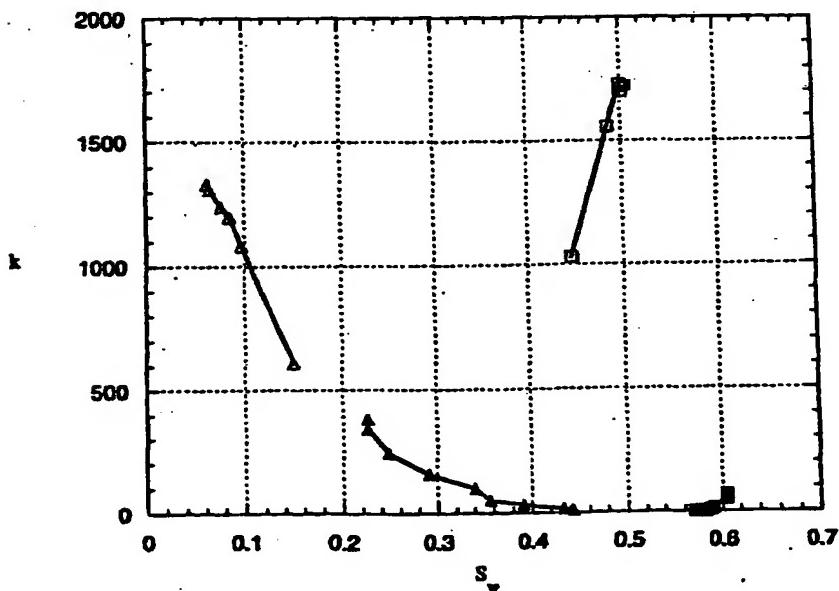
Figure 4. 20% gelant in the emulsion (run 2), fractional wet. Relative permeability curves before (open symbols) and after (filleed symbols) gel treatment for oil (triangles) and water (squares).
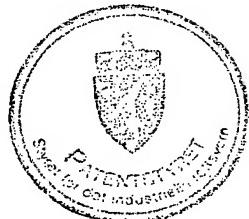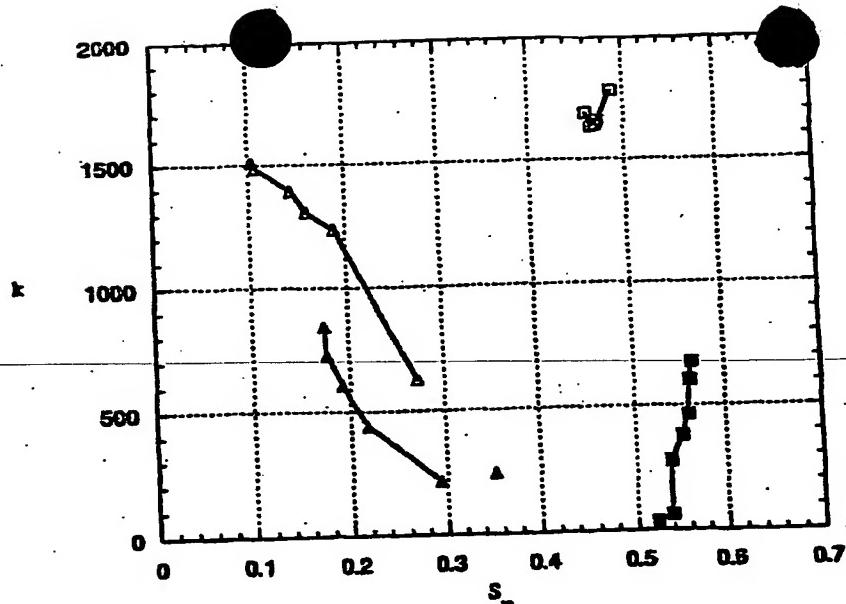
Figure 5. 25% gelant in the emulsion, fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).
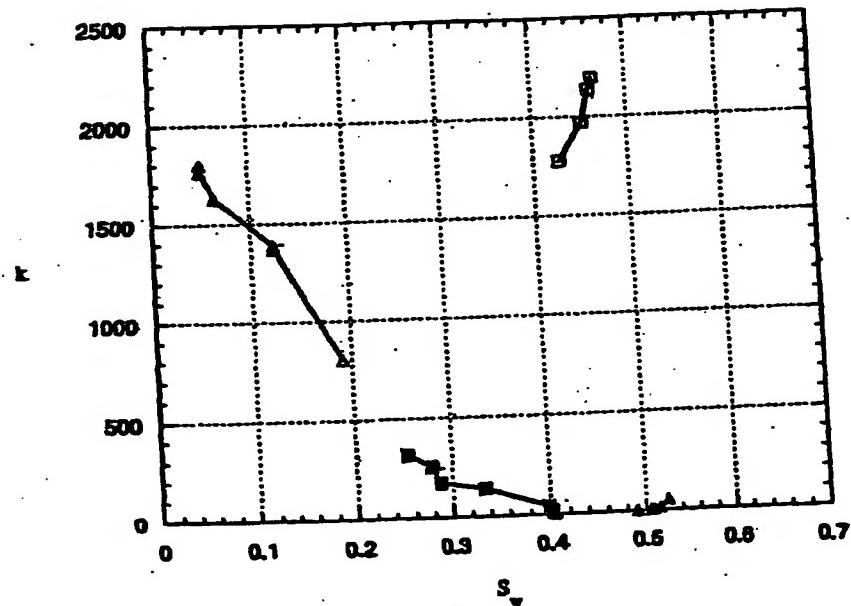

Figure 6. 30% gelant in the emulsion, fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).
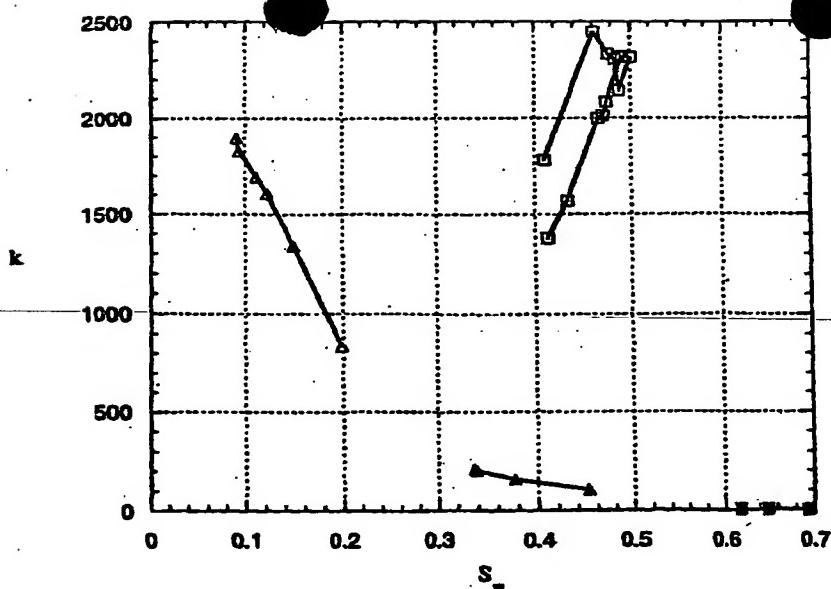
Figure 7. 50% gelant in the emulsion, fractional wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).
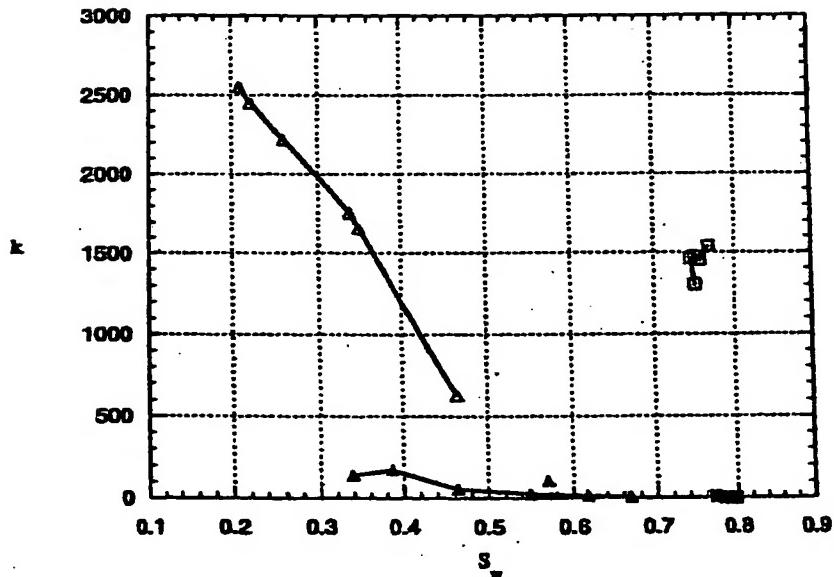

Figure 8. 25% gelant in the emulsion, water wet. Relative permeability curves before (open symbols) and after (filled symbols) gel treatment for oil (triangles) and water (squares).
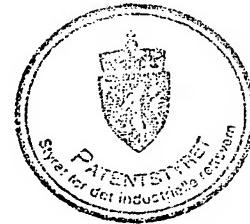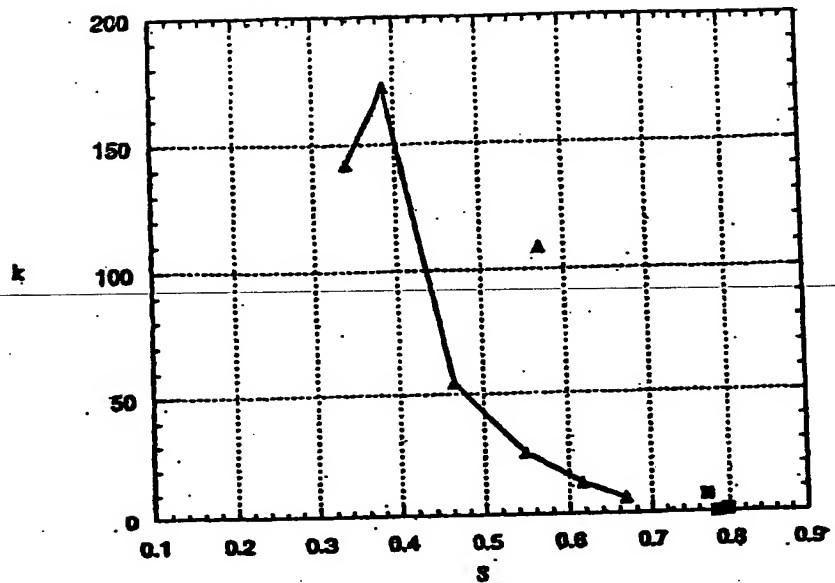
Figure 9.. 25% gelant in the emulsion, water wet. Relative permeability curves after gel treatment for oil (triangles) and water (squares).
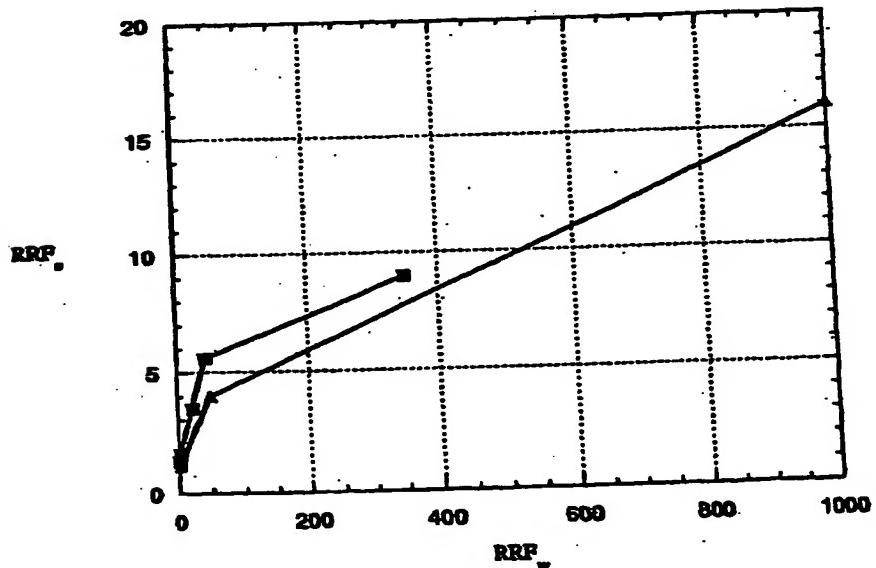

Figure 10. Residual resistance factor for oil as a function of residual resistance factor of water after gel treatment of fractional wet cores. Squares denote emulsified gel and triangles denote coinjection (data taken from 1997 Reserve gel report).
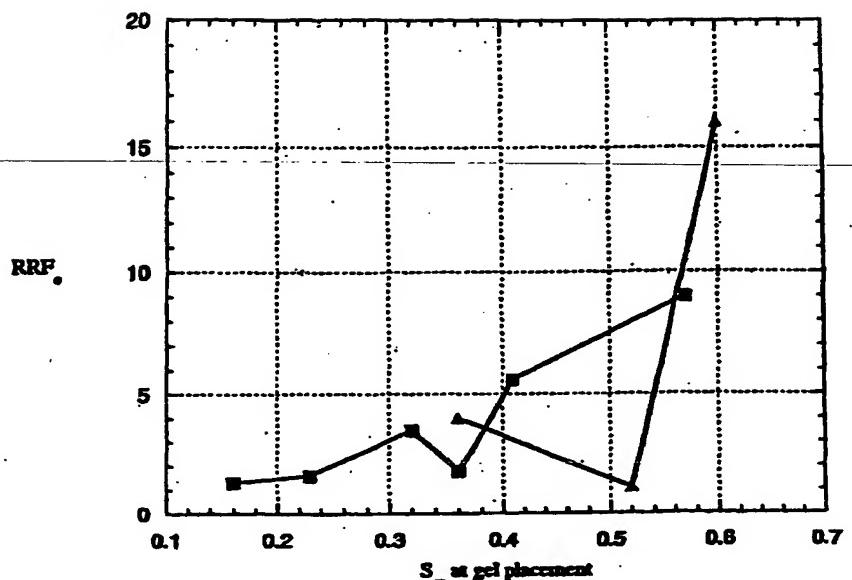
Figure 11. Residual resistance factor of oil as a function of saturation at gel placement. Squares denote emulsified gel and triangles denote coinjection (data taken from 1997 Reserve gel report).
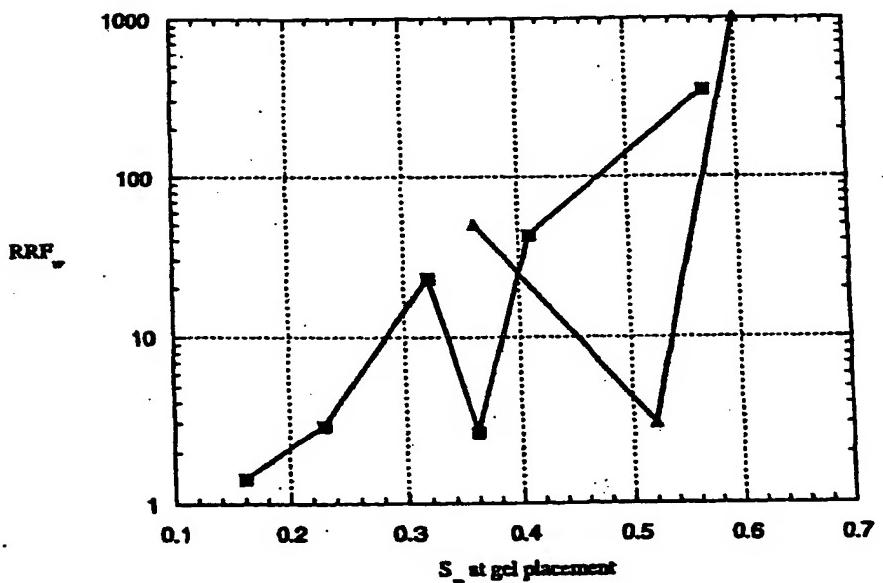
Figure 12. Residual resistance factor of water as a function of saturation at gel placement. Squares denote emulsified gel and triangles denote coinjection (data taken from 1997 Reserve gel report).